Recommendations

In this section we provide general recommendations regarding potential restoration projects on Butte Creek between the Centerville Head Dam and Highway 162.

UPPER CANYON REACH (Centerville Head Dam to the Centerville Power House):

Restoration efforts in this bedrock-dominated reach should focus on protecting the existing habitat, particularly in the accessible lower end of the reach. The reach could also be affected by activities that increase the delivery of fine sediment to the stream in the upper watershed, for example in the Butte Meadows, so these areas should not be ignored.

Spawning habitat in this reach probably is limited by sites for deposition of gravel rather than gravel supply. Addition of large logs to the reach to provide such sites may be warranted on an experimental basis, although it seems sensible to try this first on other bedrock streams such as Clear Creek below Whiskeytown Dam, where logs could be delivered to the stream by truck. Helicopters would be needed to deliver logs to the parts of this reach Butte Creek where they would do the most good, so the work would be very expensive. Experience in the Pacific Northwest indicates that cabling logs in place generally is not advisable (Bisson et al. 2000), but may be necessary on Butte Creek because of concerns about poorly designed bridges and other infrastructure downstream.

We are not recommending either for or against proposals to provide passage for salmon and steelhead beyond the study reach, since that was not within the scope of our study. Holding habitat for spring-run salmon in Butte Creek is marginal because of high water temperature, however, as indicated by the data presented in the Introduction and the high mortality in years such as 1960. Given global warming, long-term prospects for spring-run chinook salmon in Butte Creek seem bleak unless they get access to habitat at high enough altitude that temperatures will remain tolerable. This would be a major project, however, that should not be undertaken lightly and may not even be feasible; in any event, care should be taken that existing habitat such as the plunge pool at the Quartz Bowl not be adversely affected by any such effort.

LOWER CANYON REACH (Centerville Power House to Highway 99):

General Recommendations:

Substantial alluvial deposits occur along this reach of Butte Creek and make up the bed and banks of the stream in most places. The alluvial areas of this reach provide most of the spawning habitat for spring-run salmon and steelhead, and much rearing habitat as well. They also provide most of the hyporheic habitat along the creek, and support valuable riparian habitat. This reach of the stream was severely affected by hydraulic mining and dredging, although substantial recovery has occurred. More recently, the channel has been affected by bank stabilization projects and by the loss of intact tree trunks that were sawed into pieces to reduce the risk of flood damage downstream.

We recommend that the restoration objective for the channel in this reach be to allow natural processes to proceed as much as possible. This includes the disturbances that accompany natural processes of channel migration; such disturbances that are now recognized as critical for the long-term maintenance of habitat for native fishes (Naiman et al. 1992; Reeves et al. 1995;

Schlosser and Angermeier 1995; Power et al. 1995; 1996; Wiley et al. 1997), even though they may involve short-term loss of habitat.

Appropriate measures to achieve this objective include purchase of land or "erosion easements" from willing sellers. Because parcel lines typically do not coincide with geomorphic boundaries there may be opportunities to purchase and re-sell parcels with appropriate deed restrictions that would limit development to geomorphically sensible areas without removing the parcels from the tax rolls. Houses and other infrastructure that are at risk from bank erosion should be moved back away from the stream, if this is feasible. This would be a more appropriate use of public money than bank stabilization with rip-rap or similar structures that degrade public trust resources. Artificial channel "enhancements" are not an effective substitute for naturally created habitat, and are unlikely to mitigate the effects of bank stabilization measures.

We have not tried to identify specific areas along the stream that might be better suited for restoration than other areas because of high rates of channel migration or similar factors. Trying to identify such areas usually is dubious. Although it is possible to make useful predictions of long-term rates of channel migration on low gradient, meandering streams such as the Mississippi and parts of the Sacramento (Larsen 1995; Larsen et al. 1998), this is not yet possible on higher gradient, higher energy streams such as this reach of Butte Creek (Pizzuto in press)[1] The historical record and recent experience shows that the channel in this reach tends to migrate in jumps, or avulsions, with which existing models of channel migration do not deal. Avulsions also complicate intuitive assessments of erosion hazards. For example, a homeowner downstream from the Parrott-Phelan Dam spent many thousands of dollars to stabilize the bank of a channel that was abandoned by the stream a year later. It is more sensible to recognize that the channel probably has occupied any part of the valley where recent coarse-grained alluvial deposits occur, and to assume that the channel may do so again.

It is easier to identify areas where bank erosion will not occur, or will occur only slowly, because of highly resistant materials in the banks. Doing this comprehensively would have required better access to sites than we had, and in some cases subsurface sampling, so we have not tried to map such areas, although an obvious example is shown in Figure 5-1. Areas with resistant banks are better suited for homes and other infrastructure than alluvial sites, even if they are closer to the creek. Therefore, we recommend against using some arbitrary distance from the stream as a criterion for judging proposed developments.

As should be evident from our comments about large wood in the upper canyon reach, the practice of cutting up logs in the channel and on the floodplain tends to reduce the habitat value of the stream for juvenile salmonids and other organisms, and should be discouraged. Large wood has important ecological functions in alluvial channels, as described in the Introduction.

[1] Pizzuto (in press) concludes his excellent review of numerical modeling of fluvial processes with this paragraph. "The models reviewed above have several features in common. Few of the models have been routinely used in practical applications (although the 1-dimension bed material wave model of Cui et al. (in review) is currently being used in several projects). Few of the models are commercially available, and few have been thoroughly tested in a wide variety of field settings. Finally, it is important to recognize that the conceptual basis for many of the models discussed above is still being actively debated. Scientists still do not agree on the essential controlling mechanisms for many of the processes simulated by these models."

Figure 5-1: Resistant banks protect these homes in the Canyon from channel migration.

Infrastructure along the stream should be designed to let floating trees pass, if it is to be consistent with maintaining and rehabilitating environmental values in the stream.

Where re-vegetation projects are contemplated, it seems appropriate to design plantings for the existing conditions, rather than undertake expensive earthmoving projects in order to recreate some idealized riparian topography. In areas of dredger tailings with highly irregular topography it may be worthwhile to do some smoothing of the land surface if there are botanical reasons for doing so, but in terms of fluvial geomorphology *per se* such work is unnecessary. In other words, areas that are now effectively terraces should be planted with species appropriate for terraces, for example on the right bank within the Honey Run Ecological Reserve. If channel migration eventually makes floodplains of these areas the plantings will contribute useful wood to the channel, and floodplain species will recruit naturally, as is occurring in area such as the channel abandoned by the avulsion in the reserve.

Parrot-Phelan Diversion By-Pass Channel:

The sill at the entrance to the Parrot-Phelan Diversion By-Pass Channel should be raised. During flow events that move a significant amount of gravel, part of the flow passes over the sill on the left bank upstream from the Parrot-Phelan Diversion and passes the diversion in an armored artificial channel. This reduces the discharge in the main channel, and so reduces the competence of the stream to transport coarse sediment. In consequence, a bar forms opposite and downstream from the sill that increases the proportion of the flow going into the high-flow channel at a given discharge, and reducing the discharge at which water begins to flow into the by-pass (we have observed flow going into the high-flow channel at a discharge of about 1,500 cfs).[2] As the frequency of flow into the by-pass channel increases, so too does the problem of fish being stranded in the by-pass.

[2] We inspected design documents for a design discharge for overtopping the sill, or for calculations reflecting a design discharge, but found none, so the bias of the design is unknown.

Figure 5-2: Equipment removing gravel from the channel upstream from the Parott-Phelan Dam to maintain channel capacity.

At the least, the current situation creates a need to remove material from the bar periodically, using heavy equipment. This occurred in August, 1999, and again in August, 2000. Material excavated in 2000 was trucked to the right bank of the creek downstream of the Parrott-Phelan Diversion Dam, where it was placed at an elevation such that a very high flow will be required to mobilize it. Although we recognize the need to minimize releases of fine sediment during these summer low-flow operations, some method should be developed for returning the sediment to the stream. Pushing the sediment into the stream during periods of high flow seems one alternative, but it seems better to raise the sill at the entrance to the Parrot-Phelan Diversion By-Pass Channel to minimize the need for mechanically moving the sediment around the dam[3]

A potential problem occurs near the lower end of the by-pass channel, where a beaver dam has created a pond that becomes quite warm in the summer and probably creates good habitat for larval bullfrogs and other introduced species. Biological evaluation of this pond seems warranted.

Mining Ponds:

There are mining ponds in the floodplain along the right bank of Butte Creek at about Sta. 116,000 (RM 22), in an area that lies between two properties that are managed for habitat (Figure 5-3). Although these ponds do not present as severe a problem as mining ponds along streams below dams where the sediment supply has been severely reduced, the ponds would disrupt the transport of coarse sediment to the stream if the stream were to "capture" them by channel migration. This would promote further channel instability and migration in the vicinity of the ponds, and create a short-term tendency for channel incision farther downstream. Like the beaver pond mentioned above, these ponds may provide habitat for bullfrog larvae and other

[3] We inspected design documents for a design discharge for overtopping the sill, or for calculations reflecting a design discharge, but found none, so the basis of the design is unknown. We have been told that a design discharge of 10,000 cfs for the stream channel was given verbally at a 25 March 1997 meeting of the Butte County Board of Supervisors.

exotic species, and deserve biological evaluation. The ponds may provide a logical place to put clean fill that may become available at little or no cost from landslides on the road or similar sources. However, if the ponds are filled with sediments much finer than the gravels that existed before, hyporheic flow through the alluvium any be negatively affected, and when the channel eventually erodes in the former pit the fill may become a source of excess fine sediment

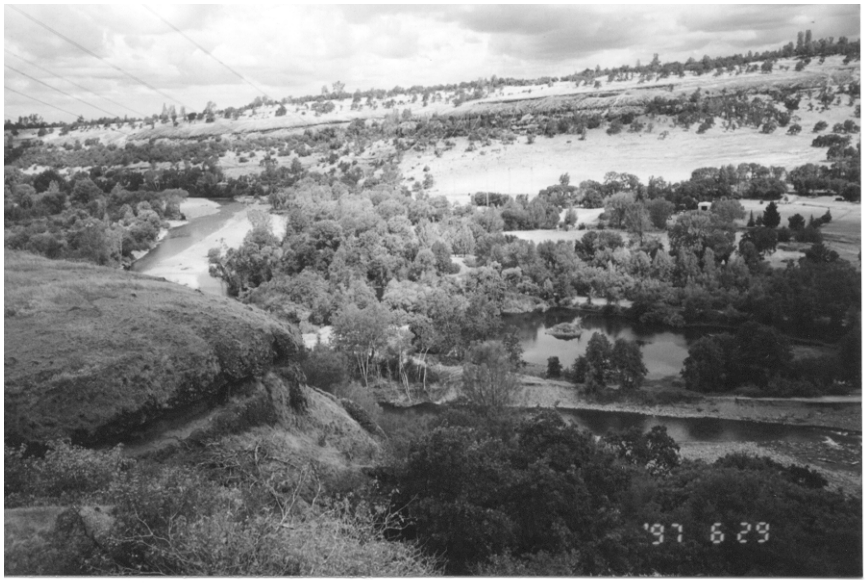

Figure 5-3: The mining pond along the right bank of Butte Creek in the Canyon Reach, in the right-center of the photograph, is now separated from the creek only by a narrow berm that shows clear signs of erosion.

Valley Reach

Opportunities for habitat restoration vary along the valley reach of Butte Creek, but generally increase with distance downstream. In some areas, such as the Virgin Valley Ecological Reserve upstream from Highway 99, there are opportunities to reestablish native vegetation on terraces. Where the creek is incised into the Red Bluff Formation, from about Highway 99 to the Oro-Chico Highway, opportunities for restoration are very limited by the high sheer stresses that occur within the incised channel. Over the lower part of the fan, opportunities for restoration are greater than in the confined reach but remain constrained by the typically close spacing of the levees and the value of property outside the levees. Farther downstream, where the levees typically are farther apart and basin clays do not support orchards, opportunities are greater still . These range from limited actions along the creek to bold development of a meanderbelt within set-back levees. The costs and benefits of such actions would also span a very wide range.

Localized riparian restoration projects within existing levees:

The opportunities for localized restoration projects within the existing levees depend on the local hydraulic conditions, as demonstrated by the experience of the Keeney Ranch Restoration Project. This project, just upstream from the Midway, provided for some restoration of riparian habitat. However, the Reclamation Board required the Keeney Project to be designed and managed so that it will have little effect on hydraulic conditions in the channel, in order to avoid

increased risk of levee failure. To the extent that such projects have to be designed to leave hydraulic conditions in the channel unchanged, the benefits to the stream ecosystem will be minor, because the existing incised channel is not well connected hydrologically to the overbank.

The available evidence indicates that the road and highway bridges at the downstream end of the Keeney Project create backwater conditions that control flood elevations in the project area, but the practical consequence of the Reclamation Board's position is that detailed (and therefore expensive) hydraulic studies will be needed for restoration projects within the existing levees. This constraint is probably weakest along the lower part of the study reach, where there is little development, so the potential losses to flooding are much less and any increased risk could be mitigated by ring levees around such infrastructure as exists. There is a good deal of land between the levees that potentially could be converted from rice field to riparian vegetation.

Ecosystem restoration projects within set-back levees:

If levees along the lower part of the valley reach of Butte Creek could be set back to meet concerns about flood conveyance, then there would be great potential for restoration of a naturally functioning ecosystem comprising both stream and riparian habitat. We cannot think of another situation in the Central Valley that offers the possibility of such a long corridor of riparian vegetation of substantial width, along a stream in which the flow regime during winter and spring is substantially natural. Such a project would benefit a wide range of riparian species, and so reduce the likelihood of future listings under the ESA. Evidence from the Sutter and Yolo by-passes (Sommer et al. 2001; Tracy McReynolds, CDFG, personal communication 2000; CDWR 1999) also suggests that such restoration could provide significant benefits to spring-run and fall-run chinook salmon, by creating good rearing habitat for emigrating fry. Unlike the by-passes, the existing straightened and incised channel offers few places for these fish to find slowly moving water in which to rest or feed.

If such a project were implemented, it should include measures to reverse the existing incision of the channel, and so to promote better connectivity between the stream and the floodplain. There has been little experience with such endeavors, so an experimental program with expert guidance would be in order. Strategically placed "plugs" made of gravel and trees seem a possible approach.

Proper evaluation of the benefits of a restored channel in the valley reach of Butte Creek for spring-run salmon would depend on development of better understanding of valley habitat use by the juvenile spring-run. A 10-year study funded by the Anadromous Fish Restoration Program is underway.[4]

[4] We suggest that the study might usefully include examination of the microstructure of otoliths from spawning adults could provide information on the early growth rates of fish that successfully complete the life cycle. Such information should be combined with development of data on measures of growth and condition from samples of fry collected at different locations along the creek. Such data would provide evidence about the relative value of the habitat at the locations. For example, the ratio of RNA to DNA in sample tissue provides an index of the rate of the short-term growth, since the amount of DNA in cells is relatively constant but the amount of RNA varies with growth rate. Such data could be used to test the hypothesis that the hydraulically simplified channel of Butte Creek provides lower habitat value than areas of the channel farther downstream or in the Sutter By-pass. This would require destructive sampling, so any such study would have to be carefully designed to take the minimum number of fish required to obtain meaningful results. Initial efforts should target fall-run fry that migrate down the channel somewhat later than the spring-run. Results from sampling fall-run fry could be used to develop a good study design for work on spring-run, and would be valuable in themselves as well.

Social and economic considerations:

There would be social and economic costs to restoration within set-back levees, including loss of agricultural land, that would need to be taken into account along with the benefits. We need to leave assessment of these costs to others (e.g., Adams et al. 2001), since it is beyond our area of expertise, but we recognize that the costs would be substantial, and would need to be weighed carefully against the benefits. We also recognize that the costs and benefits of such a project would accrue to different geographical areas; the costs would be focused in Butte County, but the long-term benefits would be more widely distributed. This raises equity issues that also would need to be addressed.

The term restoration is used here in a loose sense, because modifications to the stream over the last 150 years preclude a return to pre-existing conditions. From a geomorphic perspective, the increase in the sediment supply from mining activity, and the increase in sediment-transport capacity of the stream resulting from the leveeing and steepening of the stream and from the consequent incision, is particularly important. In conjunction with the reduction of backwater conditions in the Butte Basin by dams on the Sacramento and Feather rivers, this has resulted in the transport of silt, sand and even gravel well down into the Butte Basin. Accordingly, a restoration project in this area would develop on coarser-grained soils than occurred naturally, and the stream channel would have a somewhat different character than the anastomosing channels with steep, clay-rich banks that probably existed previously. We think the area has great potential value as aquatic and riparian habitat nevertheless.

Bridges:

Bridges along Butte Creek vary in their ability to pass large pieces of wood. The older bridges especially tend to have short spans between the piers and to become hydraulic constrictions during floods. Evidently this occurred at the railroad and Midway bridges in 1997, for example, when a drop of several feet in the water level was reported at the bridges. Replacements for these bridges should be designed with longer spans. This would be an important long-term step toward restoration of Butte Creek.

Gravel aggradation within the levees:

Concern has been expressed regarding localized areas of aggradation in the channel, for example in the reach upstream from the "Big Bend." We recommend caution regarding removal of such deposits, which provide hyporheic habitat that is very limited in this reach. We suspect that the aggradation may be episodic, alternating with periods of incision. We suggest that a period of monitoring precede any removal of gravel, unless hydraulic modeling demonstrates a significant decrease in the flood conveyance capacity of the channel.